

MUSKWA WOLF MANAGEMENT PROJECT
OF NORTHEASTERN B.C.
1984-85 Annual Report

by

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ABSTRACT

This report identifies work completed for the Muskwa wolf management program for the 1984-1985 biological year. Wolf and ungulate population response to wolf removal are documented. One hundred and ninety-eight wolves were removed from 13 520 km² (5220 mi²) of the Muskwa program area. Moose in the 1984 moderate wolf reduction area responded with four times as many calves per 100 cows as had been present the previous (prereduction of wolves) year (or as are found in untreated wolf areas). During two years of high wolf numbers and one year of lower, cow moose are estimated to have declined by 27%. Elk in the 1984 moderate wolf reduction area responded with three times as many calves per 100 cows as had been present the previous year. During two years of high wolf numbers and one year of lower, cow elk are estimated to have declined by 6%. Mountain sheep in the 1984 moderate wolf reduction area responded with two times as many lambs per 100 ewes and three times as many yearlings per lambs the previous year (proportionally) as had been present prior to reduction of wolf numbers. Caribou continue to show good recruitment. A viable - though reduced - wolf population remains in the area.

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INTRODUCTION

The management of wolves in the Muskwa unit and elsewhere in northeastern B. C. (Figs. 1 and 2) has proceeded through several phases. During the second quarter of this century, the wolf was generally regarded as a major scourge of ungulate herds but little was done to modify the situation. Woodsmen travelling in the northeast of British Columbia at that time refer to a general paucity of game animals.

In the 1950's, wildlife agencies across the wolf's range started to reduce wolf numbers, primarily with toxicants. These programs were extensive and intensive in northern British Columbia including the Muskwa project area. The time extent of these programs varied; wolf reduction in northeastern British Columbia continued officially into the mid-1960's. However, substantial illegal wolf reduction effort continued into the early 1970's when increased federal restriction on the availability of toxicants and general loss of momentum appeared to have left illegal reduction at a low level. In contrast to the paucity of the second quarter of the century, numbers of game animals in northeastern B. C. during the 1960's and early 1970's were at high levels while wolf numbers were low.

Wolf populations built up following the cessation of reduction effort. Surveys in northeastern B. C. showed wolves to average one per 148 km² (57 mi²) by the 1978-79 winter (B. C. Fish and Wildlife Branch 1984) and, by 1984, were more than five times that level. During this period of wolf increase, ungulate herds progressively deteriorated with isolated herds being eliminated and declines general and severe.

It was against this backdrop of increasing wolf numbers and decreasing ungulate numbers that the Muskwa wolf management program was initiated (Elliott 1982, 1984). The program aimed to restore ungulate numbers and productivity in the Muskwa area through reduction in wolf numbers, but without eliminating the wolf or endangering the long-term existence of local wolf populations. The program area lies southwest of Fort Nelson, British Columbia and is described in Elliott (1984).

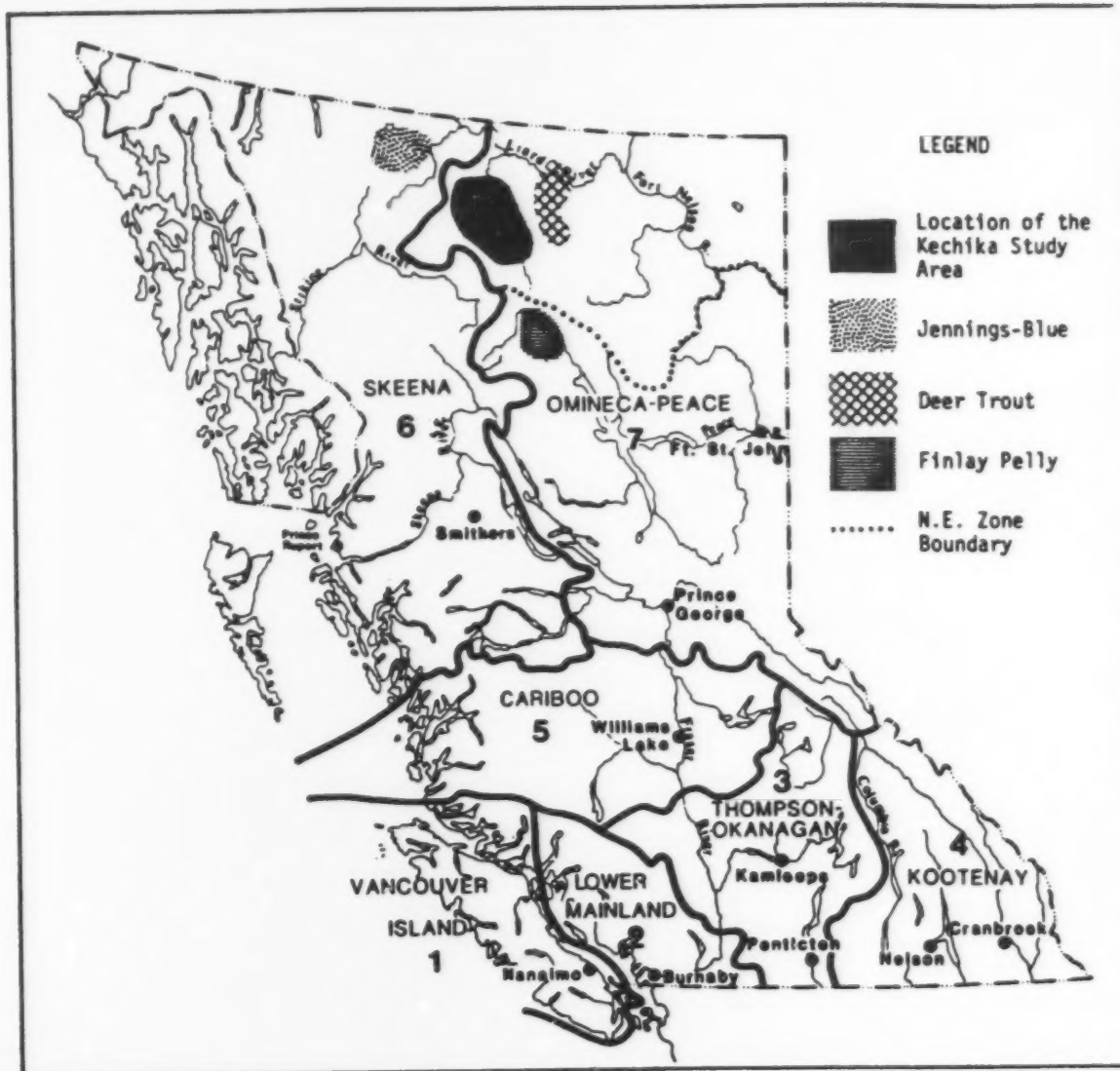
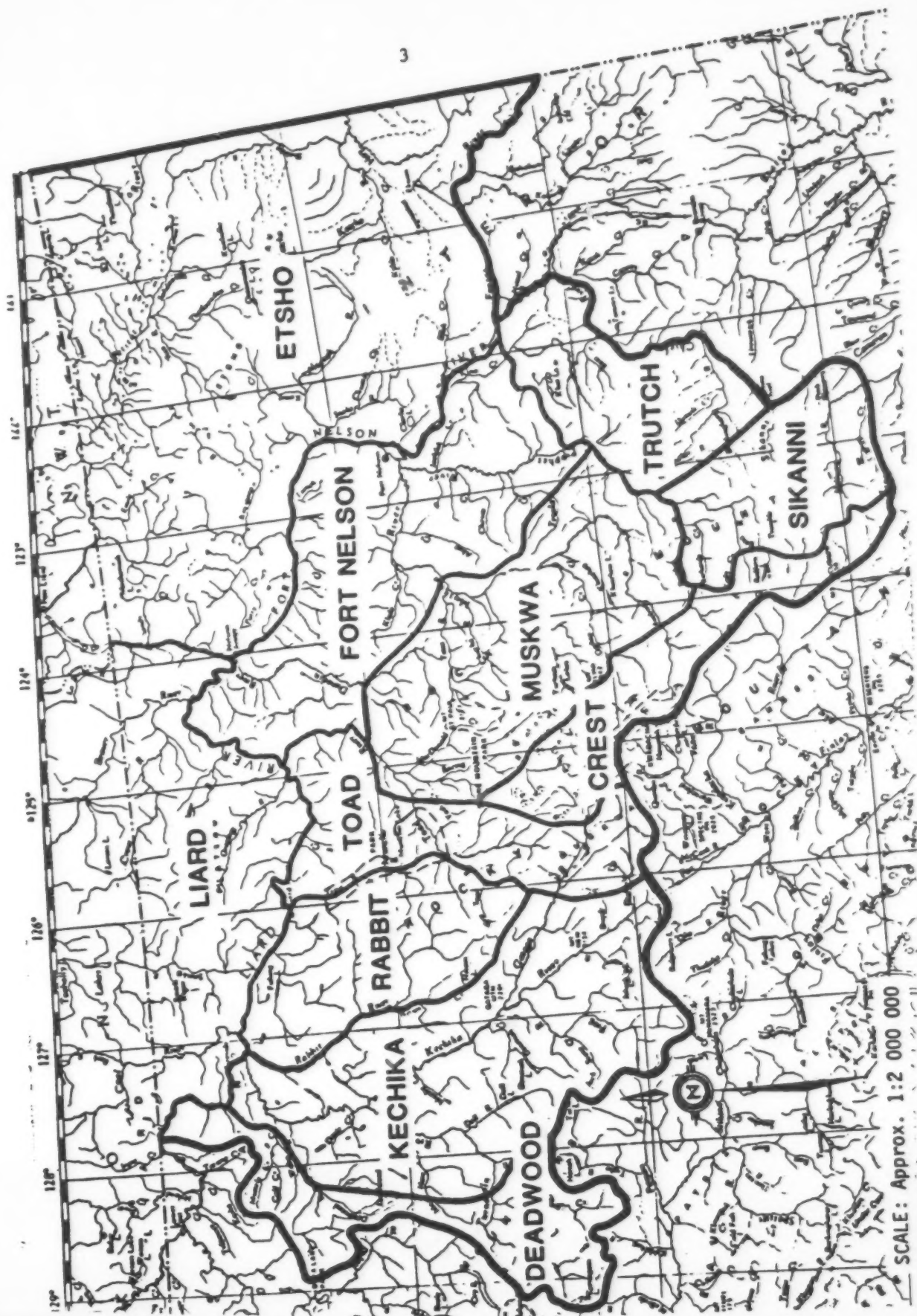


Figure 1. Map of British Columbia showing the location of areas referred to in the text and the zonal NE administration boundary.



METHODS

WOLF SURVEYS AND REDUCTION

Wolves were removed during January to March 1985 (plus incidentally earlier in the winter) from a 13 520 km² (5220 mi²) portion of the project area. In addition, wolves were inventoried over 17 350 km² (6700 mi²).

Wolves were inventoried and removed by using both fixed-wing and helicopter. Inventory proceeded by flying likely wolf travel routes until fresh sign was spotted. The trail was then followed until either the wolves were seen or the tracks separated sufficiently to enable a count. When necessary, track counts were confirmed by landing and examining the sign in detail.

Wolf removal was done by government personnel from a Bell 206 helicopter. Conventional shotguns loaded with SSG shot were used.

MOOSE AND ELK SURVEYS

A similar methodology was used for elk and moose population composition surveys. In both cases, transects were flown for the purpose of determining the age and adult sex ratios. Transects were uniformly spaced straight lines (modified where necessary for feasibility in rough topography) and predetermined on 1:250 000 scale maps. This pattern was assumed to be random relative to the animals and thus produce unbiased estimates. Surveys were undertaken in November, February, and March.

Winter moose were classified as to calf, non-calf male, or non-calf female based upon shape, size, presence or absence of light vulval hair, head colouration, and antler scars. In autumn, moose were classified as to calf, yearling male, adult male, or non-calf female based upon size, presence or absence of antlers, antler configuration, and vulval hair. Elk were classified as to calf, yearling male, 2+ male, or non-calf female, based upon size, shape, and antler presence and configuration. Elk monitoring was confined to the range of the main herds found in the Muskwa, Kluachesi, Gathto, Tuchodi, and Chlotapecta drainages.

Moose density was estimated for the Tierney Creek area (Fig. 3) by stratified random block surveys using a ratio estimator (Gasaway et al., in prep.). The survey area was located well within the boundary of the wolf reduction area. Sample units were polygons whose boundaries were defined by recognizable landscape features such as gulleys, ridges, and streams. Blocks were searched intensively by flying closely spaced parallel transects with a helicopter.



Figure 3. Tierney Creek moose density area.

Moose density was also estimated using the elk estimate blocks for the Core area (see below and Fig. 4) allowing a comparison with a similar count done in 1982. In this situation, blocks from the stratified random block survey for elk were also enumerated for moose. This is statistically legitimate but not efficient (for moose) so the confidence limits were expanded.

Moose density was further estimated for the Pink area of Management Unit 7-44 (Fig. 5) both in March 1979 and December 1984. These surveys are discussed elsewhere (Ministry of Environment 1984, Harper, in prep.) and follow a normal stratified random block sampling scheme. Approximately one-half of this survey area is within the Muskwa project area.

Elk density was estimated in the Core elk area (Fig. 4), an area which was also surveyed in 1982 (Elliott and Webster 1982). This area was stratified into low, high, and very high elk density strata. The boundary between high and low was modified slightly between the two years to incorporate, within the high stratum, two areas which were improved through burning in 1983. Procedure was similar to that of the moose density estimate survey excepting that the higher densities required smaller blocks in order to avoid bias due to mixing of animals on the blocks.

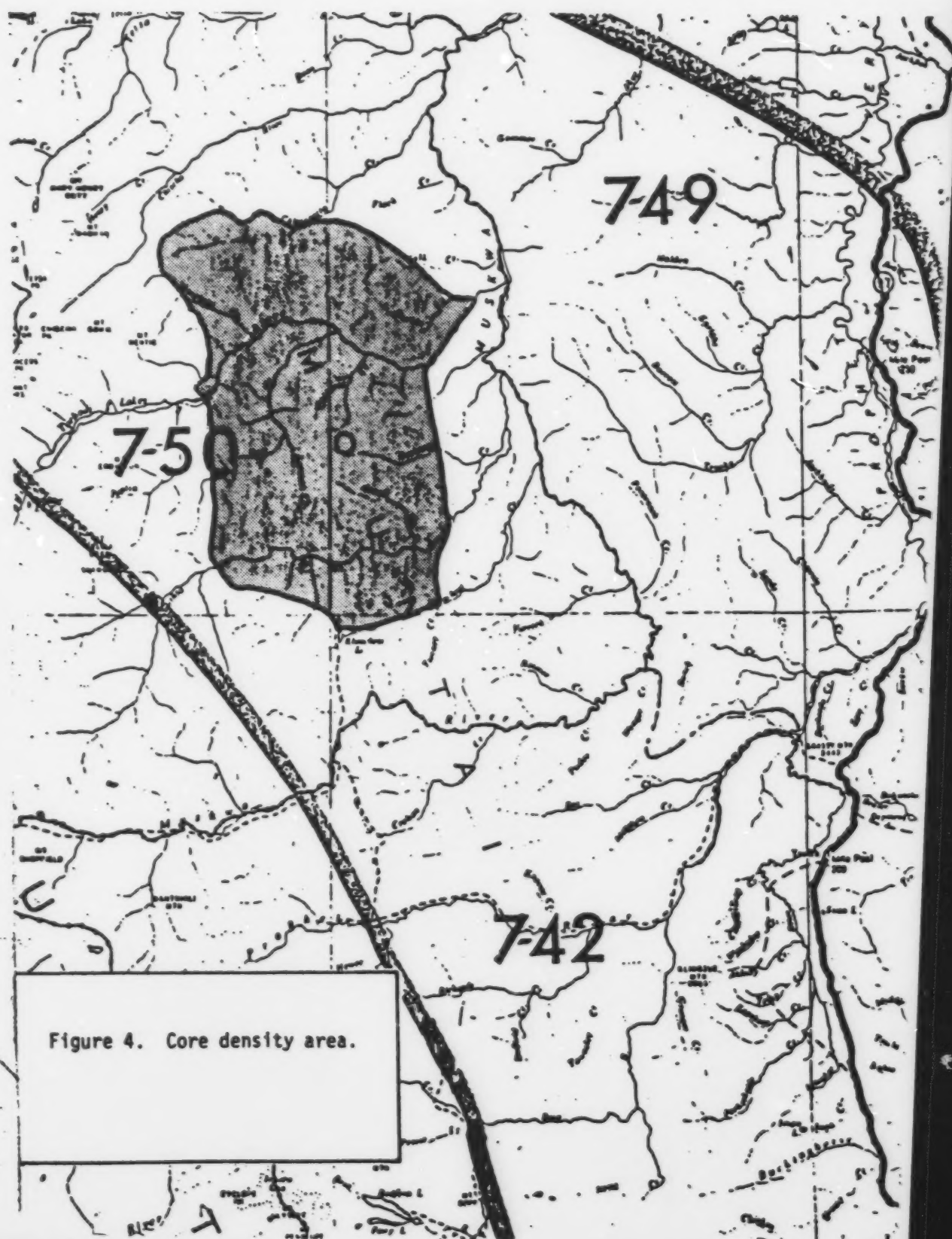
MOUNTAIN SHEEP SURVEYS

Mountain sheep were inventoried in February-March from a Bell 206 helicopter. Complete units were searched through all sheep habitat types and at all elevations and aspects by flying contours. Speed and closeness were varied so that the observers were placed optimally according to visibility.

Animals were classified as to lamb, yearling, 2+ year female, 2 year male, and 3+ year male based upon size and horn characteristics. Because of the wider distribution of males, this survey method for smaller units may have been biased against males; however, ratios of juveniles to ewes were believed to be unbiased.

CARIBOU SURVEYS

Caribou were surveyed in March in the vicinity of the rutting benches between the Tuchodi and Tetsa Rivers plus the Racing River. Animals were classified as to calf and adult based upon size and antler status.



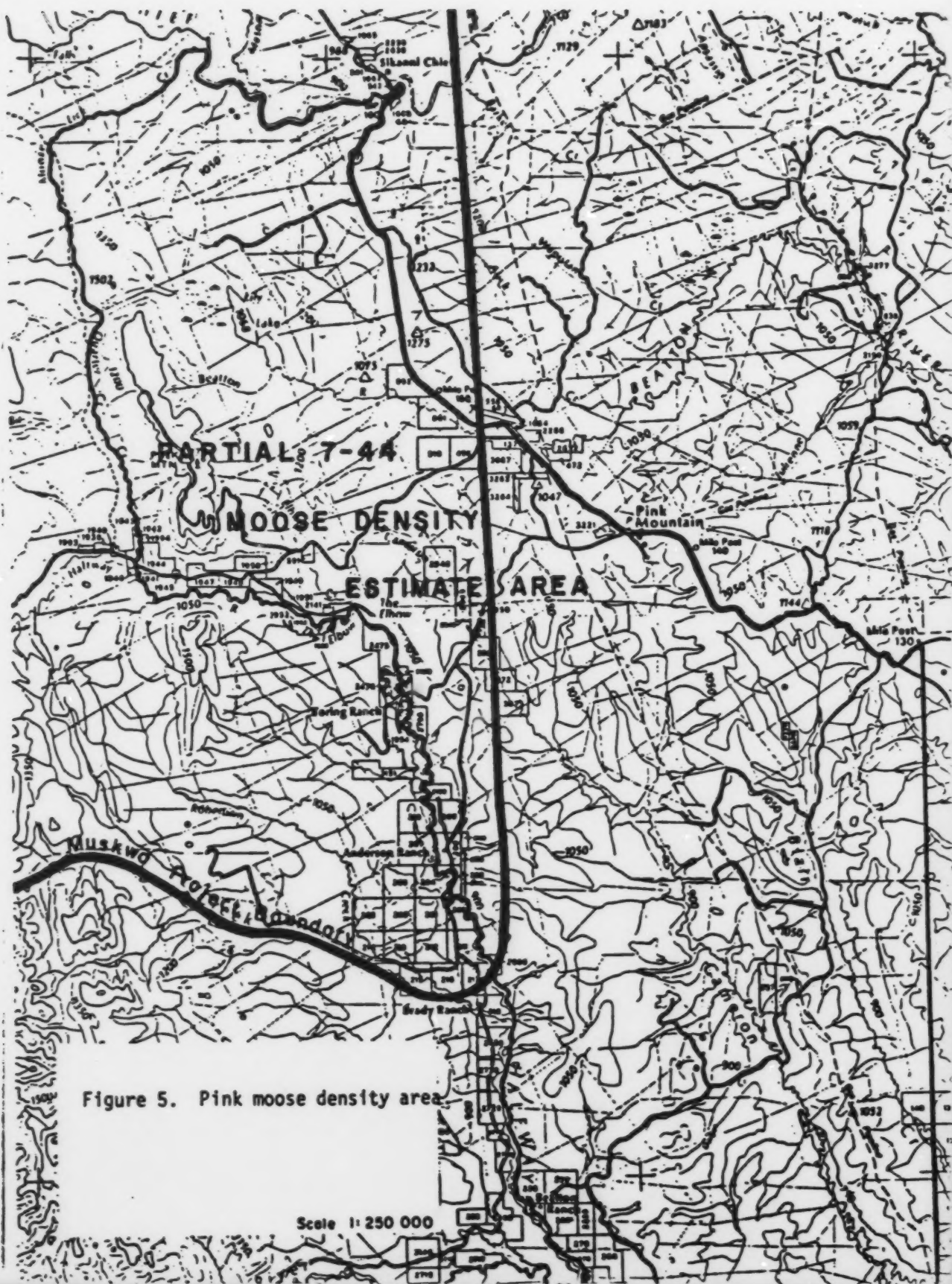


Figure 5. Pink moose density area

Scale 1:250 000

DATA ANALYSIS

Sex and age composition data were expressed as ratios (number per 100 females) or as percentages of the total. The recruitment rate was defined as the proportion of a population of a given age or older, for one or both sexes, which that given age group comprises.

Finite rates of population change (λ) can be calculated from the equation

$$\lambda = \frac{1-M}{1-R}$$

where R is the recruitment rate and M is the mortality rate for the animals of greater age than the recruitment age. $(\lambda-1)*100$ yields the percent population growth.

Analysis of stratified random block survey data followed procedures outlined by Gasaway et al. (1983)

RESULTS

WOLF SURVEY AND REDUCTION

Figure 6 and Table 1 summarize the 1983-84 late winter wolf numbers and wolf removal level. The total area surveyed was about 12 000 km² (4650 mi²). This area contained some 463 wolves in 73 packs (groupings of two or more wolves) and 14 singles for an average 26 km² per wolf (9.8 mi² per wolf).

The 1983-84 restricted wolf-reduction (treated) area was about 6800 km² (2600 mi²). This area contained 303 wolves in 51 packs and 11 singles. One hundred and eighty-two (60%) of these wolves were removed.

Figure 7 and Table 2 summarize the 1985 wolf numbers and wolf removal level; 198 (77%) of 256 wolves in the reduction area were removed. Fifty-three (26%) of 204 wolves encountered in 1984-85 were black while the remaining 151 (74%) were grey. Eighteen (53%) of 34 wolves of known-sex greys were females; 16 greys (47%) were males. Sixty percent of the known sex were females while 42% of the known-sex blacks were female. Seven (21%) of 34 aged animals were 1984 pups.

Total cost (aircraft, fuel, equipment, travel) per wolf removed was \$140. This is similar to costs in previous years for this type of removal in the northeast.

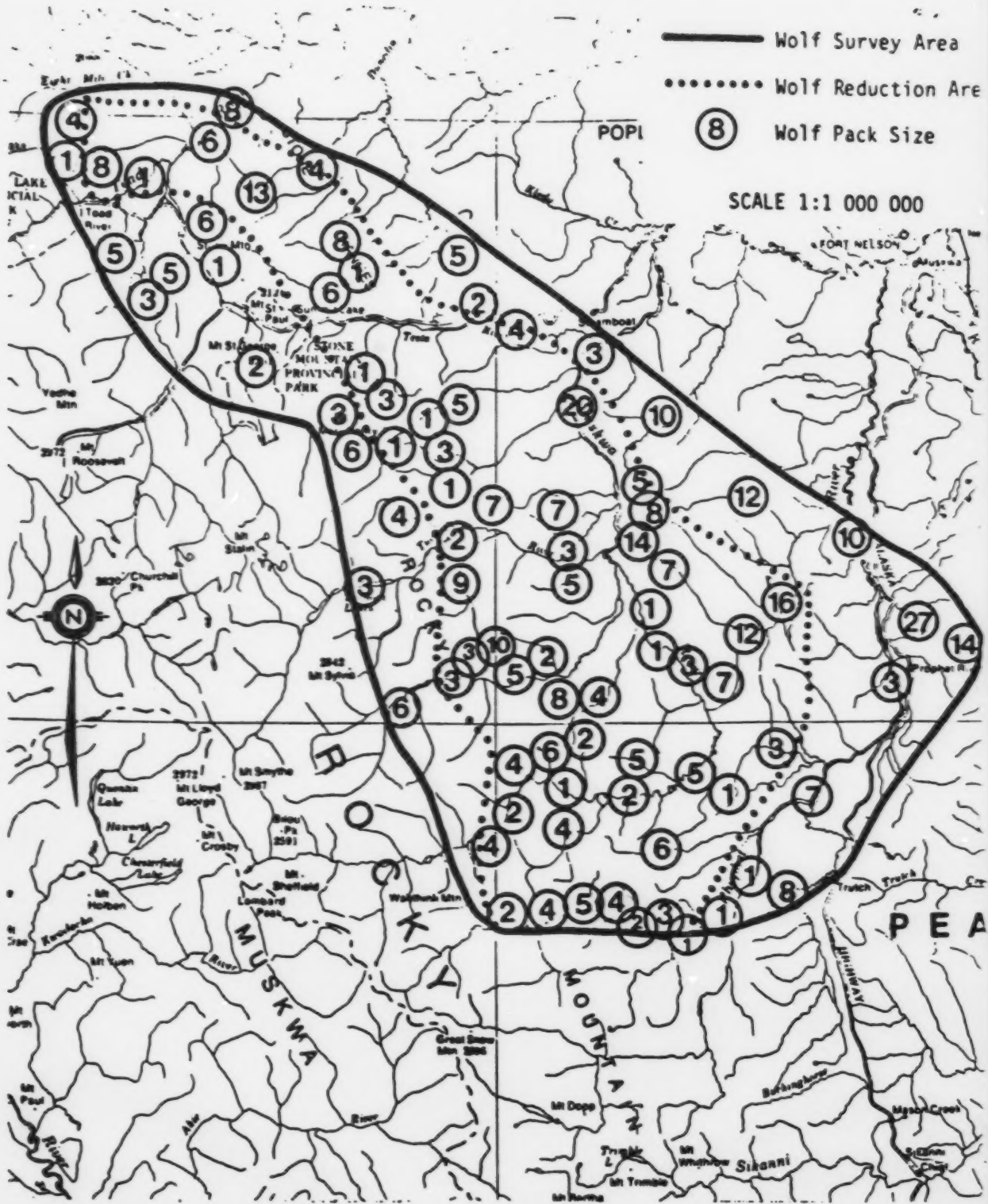
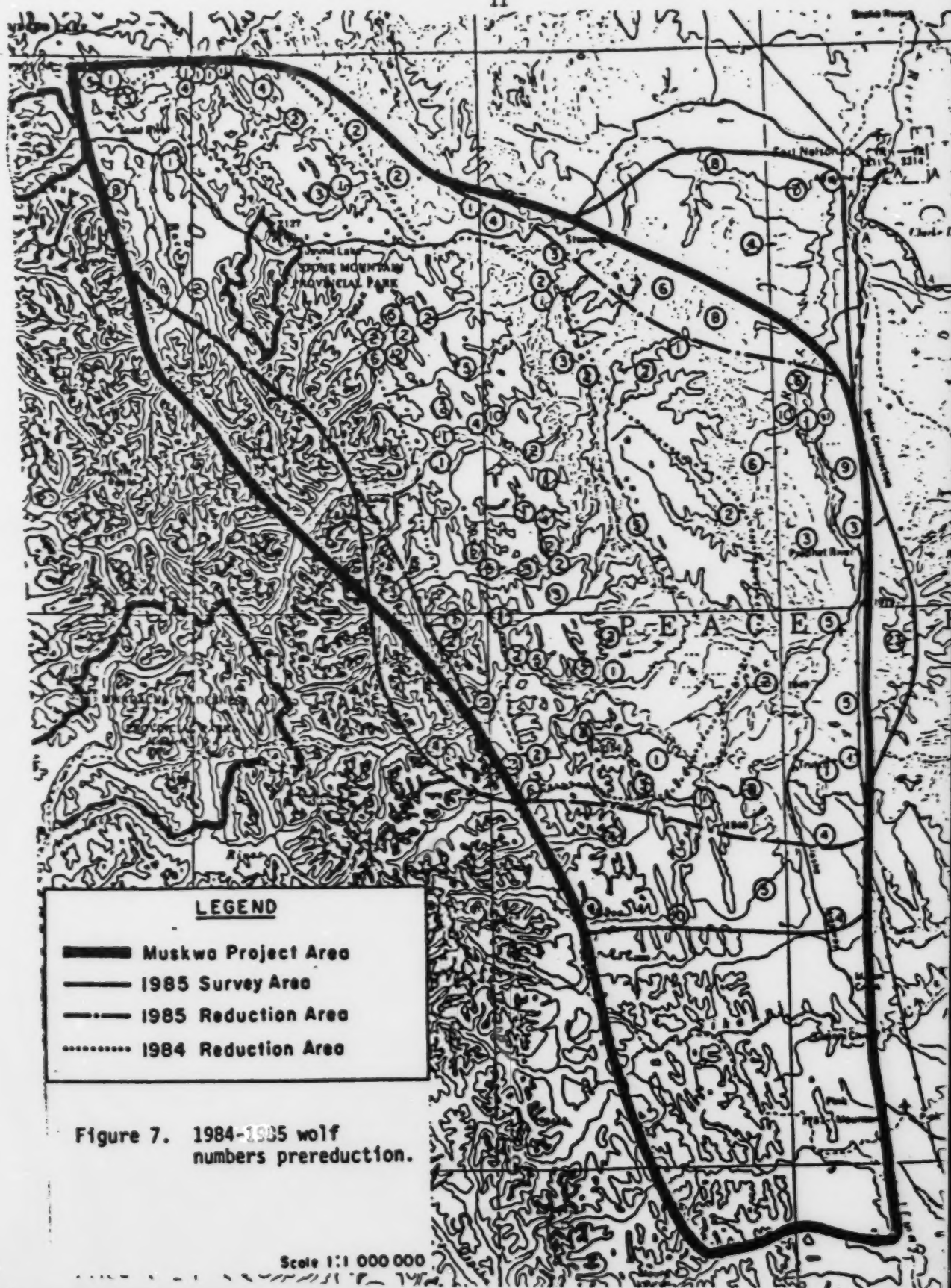


Figure 6. Wolf Distribution - 1983-1984.



MOOSE SURVEY

The 1984 autumn moose survey (Table 3) sampled 856 moose. It was found that the yearling to cow proportion (10.9/100 cows) was basically the same as that from spring (Elliott 1984). This survey covered most of the 1984 removal area.

The winter survey (February - March 1985) considered only the population estimate areas (Appendix A) that were centrally located in the removal area plus the Crehan (360 km²), an historically low wolf area in the Muskwa (Elliott 1984). The population estimate surveys covered 1735 km² and some 515 moose. The first of these areas - the Core area - is examined in Appendix A. This area covers 1375 km² and the population estimate survey involved 48 sample units. In 1982, this area had an estimated 1.0 moose/km² (2.55/mi²). However, in 1985, after two years of heavy predation and one year of only moderate predation (wolf numbers were reduced in 1984), this area had only an estimated 0.8 moose/km² (1.98/mi²) or a 22% decline. By considering only cows, the effects of annual juvenile recruitment and hunting (open for adult bulls only) can be excluded. Assuming an unchanged sex ratio, there were an estimated 842 cows in 1982 versus 617 in 1985 or a 27% decline. This is approximately the decline predicted (Elliott 1984) based upon recruitment data.

The Tierney area (407 km²) was surveyed much more intensively than the Core area. It will provide a basis for estimating population changes only during the period of low wolf numbers (as no previous estimates have been done here). Appendix B presents the basic data for this unit. There were an estimated 686 moose at 1.7 moose/km² (4.3/mi²). This is approximately twice the density of the Core area and should provide a useful comparison of moose population response to low wolf numbers for different initial moose densities.

The Tierney survey being specifically designed for moose with multiple strata and three times the coverage will supply a more definitive identification of population change than will the Core. Regardless, at expected maximum rates of population increase, wolf numbers must be kept low into 1988 to distinguish a population increase conclusively ($P > 0.90$). Realistically, there must be low wolf numbers through to 1989 or 1990 to distinguish these increases.

The Pink survey area of 920 km² provided a contrast to the more central units in the Muskwa. The southern boundary of the Muskwa program area represents the approximate boundary between high and moderate wolf numbers. To the south, there is a year-round program of wolf management (with full time personnel) related to agriculture conflicts. In addition, there are many more people and roads facilitating reduction of wolf numbers by the general public. There are still healthy, vigorous wolf populations; but the densities are less than for the Muskwa. Thus, both in 1979 and 1980 (the last years wolves were counted south of the Muskwa program area), there was only one-third the density of wolves just to the south of the boundary as there was in the southern third of the Muskwa area (Elliott, unpubl. data). The Pink survey area, therefore, represents a transition area between high and moderate wolf numbers.

Appendix C presents the results of the February 1979 and December 1984 Pink area moose survey. At that time, there was an estimated 1.7 moose/km² (4.3/mi²). By December 1984 the numbers had declined by 40% to an estimated 1.0 moose/km² (2.55/mi²). This area is atypical, however, because it has not had the continuous cow/calf hunting ban present during this period, in the remainder of the Muskwa program area. This has likely confounded the population growth rate such that a population with a moderate annual calf survival (18-24% winter calf recruitment between 1978 and 1984 (Elliott 1982) has declined more rapidly than otherwise.

The Tierney and Core areas' data allow an estimate of the late winter moose proportions for the 1984 wolf-reduced portion of the Muskwa. Table 4 presents these data adjusted for land area and assuming yearling proportions (by sex) are unchanged from autumn. The Muskwa had 36 calves per 100 cows, four times the number of calves (per 100 cows) that survived in the Muskwa prior to moderate wolf reduction (Elliott 1984). In further contrast, the February-March 1985 calf proportions from the more heavily wolf-reduced Kechika were 61 calves per 100 cows (twice as many), while the calf proportions in the untreated wolf Blue Jennings were similar to the Muskwa prior to wolf reduction at five calves per 100 cows (Elliott 1985).

The historically low-wolf Crehan portion of the Muskwa (assuming yearling-to-cow proportions similar to the nine month-to-cow proportions of the previous year) showed an increase in moose calf proportions. Calves increased from 29 per 100 cows prior to controlled wolf reduction in 1984 to 51 in 1985 (80 cows (2+ yrs.), 41 calves, 9 female yearlings, and 59 bulls (1+ yrs.): total of 189 moose) approaching the wolf-reduced Kechika proportions for moose calves.

ELK SURVEY

Table 5 presents results of the autumn elk transect survey flight. This survey was undertaken to obtain an adult (2+ yrs.) sex ratio - a value not well derived by the winter density estimate survey - plus juvenile-to-adult proportions for comparison with the winter data 24 adult bulls, 12 yearlings, and 42 calves per 100 adult cows were seen. Estimated yearling proportions were down slightly since February-March, 1984 when there were an estimated 14 calves per 100 cows (Elliott 1984). The substantial jump in calf proportions to 42 calves per 100 cows should, if maintained, be reflected in two years in an increasing adult bull to cow ratio.

The February-March elk survey involved a stratified random sampling inventory of the Core area. In 1982 (Appendix D), that area of 1451 km² (561 mi²) contained an estimated 3.0 elk/km² (7.7 elk/mi²) or 4313 elk. In 1985 (Appendix D), the area contained a similar density 2.9 elk/km² (7.6 elk/mi²) or 4267 elk; however, the herd composition was quite different (Table 6). In 1982, with declining recruitment and increasing wolf numbers (Elliott 1984), there were low calf numbers and, assuming a 50:50 yearling sex ratio, more yearlings than calves. In 1985, with increasing recruitment and declining wolf numbers, there were higher calf numbers and more calves than yearlings. With two years of high wolf numbers and one of moderate, the apparent slight decline in cow numbers (6%) is approximately the decline expected based upon recruitment data (Elliott 1984).

The Core survey was designed to measure elk population change during reduced wolf numbers. At expected maximum rates of population increase, wolf numbers must be kept low into 1988 to distinguish an elk population increase conclusively ($P > 0.90$). Realistically, there must be low wolf numbers through to 1989 or 1990 to distinguish these increases.

Table 7 summarizes calf and yearling proportions in the Muskwa (Core area) for the previous four years. Apparently, by comparing the 1985 yearling proportion to both the 1984 calf proportion and the autumn yearling proportion, the yearling estimate is likely biased too high. This results from the survey being stratified to total elk, which is largely cows and calves, rather than to yearlings. The usual transect technique is less prone to this bias.

Table 8 summarizes these same statistics in the Crehan for the previous three years with 507 elk surveyed in that area in February-March 1985. As expected (Elliott 1984), the greater seasonal movement of the elk (relative to moose) out of the Crehan has resulted in the juvenile proportions being similar to those of the reduced-wolf Muskwa as a whole. Further, for both the Muskwa as a whole and the Crehan, a substantial threefold increase in the proportion of calves occurred once wolf numbers were reduced.

MOUNTAIN SHEEP SURVEY

Table 9 presents results of the mountain sheep survey flight. Table 10 places these proportions in historical perspective. Following a moderate reduction in wolf numbers in 1984, lamb proportions nearly doubled and yearling survival (as estimated from yearlings/lambs the previous year) more than tripled. These numbers show an improvement compared to juvenile mountain sheep proportions in wolf-untreated areas such as the untreated portion of the Kechika or the Blue Jennings (Elliott 1985) although the more reduced wolf area of the Kechika shows even higher juvenile proportions (Elliott, op. cit.).

CARIBOU SURVEY

Table 11 presents results of the caribou survey flights. This species, which represents only a small portion of the available large mammal component, continues to show high recruitment.

Table 1. Wolf status in the Muskwa program area, February-March 1984.

	Area km ²	Area mi ²	No. of wolf packs ^a	No. of wolves	Km ² (mi ²) per pack ^a per wolf		Wolves per pack ^a
Total area pre-reduction	11782	4549	73	463	161(62)	26(10)	6.2
Untreated area	5006	1933	22	160	227(88)	31(12)	7.1
Treated area prereduction	6775	2600	51	303	133(51)	22(9)	5.7
Treated area postreduction	6775	2600	--	121	---	56(21)	---

^a excludes single wolves

Table 2. Wolf status in the Muskwa program area, 1984-1985 Winter.

	Area km ²	Area mi ²	No. of wolf packs ^a	No. of wolves	Km ² (mi ²) per pack ^a per wolf		Wolves per pack ^a
Total survey area	17440	6700	73	350	239 (92)	50 (19)	4.5
1984 reduction area	6775	2600	36	145	188 (72)	47 (18)	3.7
1985 reduction area	13570	5220	59	256	230 (88)	53 (20)	4.0
Treated area postreduction	13570	5220	--	58	---	200 (77)	---
Untreated area	3870	1490	14	94	276 (106)	41 (16)	6.7

^a excludes single wolves

Table 3. Moose proportions in the Muskwa, November 1984.

Category	Number	Proportions	
		No. per 100 cows (2+ yrs)	% of total
Adult cows (2+ yrs)	440	--	51.4
Adult bulls (2+ yrs)	235	53	27.5
Yearlings ^a	48	11	5.6
Calves	133	30	15.5
	856		

^a assumes a 50:50 sex ratio

Table 4. February-March 1985 moose proportions in the 1984 reduced wolf portion of the Muskwa.

Category	Proportions ^a	
	No. per 100 adult (2+ yrs) cows	% of total
Cows (2+ yrs)	100.0	53.8
Bulls (2+ yrs)	40.0	21.5
Calves	36.0	19.4
Yearlings	9.7	5.2

^a total sample size = 515

Table 5. Elk proportions seen during Muskwa transect flights, November, 1985

Category	No. seen	No. per 100 cows (2+ yrs)
Cows (1+ yrs)	412	
Calves	163	
Bulls (2+ yrs)	93	
Yearling Bulls	<u>23</u>	
Total	<u>691</u>	
Cows (2+ yrs)	389	100
Calves	163	42
Bulls (2+ yrs)	93	24
Yearling ^a	<u>46</u>	12
Total	<u>691</u>	

^a assumes a 50:50 yearling sex ratio

Table 6. Core elk herd composition 1982 and 1985.

Category	No.	1982		No.	1985	
		No./100 cows	% of total		No./100 cows	% of total
Cow (1+ yrs)	2905	100	67	2736	100	64
Calf	583	20	14	1128	41	26
Bull (2+ yrs)	312	11	7	157	6	4
Yearling Bull	<u>513</u>	18	<u>12</u>	<u>244</u>	9	<u>6</u>
	4313		100	4265		100

Table 7. Juvenile elk proportions in the Core area of the Muskwa, February-March.

Year	Yearlings per 100 cows (2+ yrs) ^a	Calves per 100 cows (2+)
1982	23.9	20.9
1983	10.0	13.8
1984	13.1	14.1
1985	19.6	45.3

^a assumes 50:50 sex ratio in yearlings

Table 8. Juvenile elk proportions in the Crehan area of the Muskwa, February-March.

Year	Yearlings per 100 cows (2+ yrs) ^a	calves per 100 cows (2+)
1983	34.0	26.0
1984	22.0	17.8
1985	16.3	45.6

^a assumes 50:50 sex ratio in yearlings

Table 9. Recent historical mountain sheep juvenile proportions seen during Muskwa surveys, February-March 1984.

	Category			
	Ewe (2+ yrs)	Lamb	Yearling	Total
Number	621	222	50	893
Number per 100 ewes (2+)	100	35.7	8.0	

Table 10. Recent historical mountain sheep juvenile proportions in the Muskwa, February-March.

Year	Lambs /100 ewes (2+ yrs)	Yearlings /100 ewes (2+ yrs)	Yearlings(yr t+1)
			Lamb (yr t) $\times 100$
1981	40.2	27.3	----
1982	36.8	25.0	62.2
1983	30.2	7.0	19.0
1984	21.2	3.5	11.6
1985	35.7	8.0	37.7

Table 11. Caribou proportions in the Muskwa, February-March 1985.

Area	Number		
	Adults	Calves	Total
Tuchodi Tetsa	142	37 (20.8) ^a	179
Racing	114	31 (21.4)	145

^a percent of total in brackets

CONCLUSIONS

This project still has several years to completion; however, several features are apparent.

- 1) There is a strong positive response in moose, elk, and mountain sheep juvenile survival when and where wolf numbers are lowered. This highlights the role of the wolf in the initial declines and indicates the utility of lowering wolf numbers as a management tool.
- 2) The present removal method is low cost and effective to the level necessary for the program. It is also the most selective procedure available. Most wolf carcasses are salvageable.
- 3) If ungulate increases are less than maximum, wolf removal may have to continue through 1989 or 1990 to distinguish the increases statistically.
- 4) The use of uniformly spaced transects, random to animal locations, appears to provide less biased population composition data than random sample blocks stratified to overall animal density.
- 5) The long term viability of the wolf population in the reduction area is in no way threatened.
- 6) Hunter harvest of female and juvenile ungulates, coupled with even moderate wolf predation, can accelerate declines.

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Appendix A.

Core area - moose data and statistics,
1982 and 1985

Core area, moose data, 1982.

Plot size (km ²)	adults	calves	total
3.34	1	0	1
4.04	3	0	3
2.91	8	0	8
2.89	1	0	1
3.26	9	0	9
3.79	0	0	0
2.54	4	0	4
9.61	5	0	5
3.68	1	0	1
3.01	5	0	5
4.18	2	0	2
1.84	2	0	2
3.39	2	0	2
2.89	5	0	5
2.79	0	0	0
2.81	2	0	2
3.76	1	1	2
4.34	1	0	1
4.28	0	0	0
4.71	2	2	4
1.02	2	1	3
3.24	0	0	0
1.67	4	3	7
1.55	0	0	0
3.34	0	0	0
3.79	3	2	5
2.77	0	0	0
3.16	5	2	7
2.41	5	0	5
2.67	7	0	7
2.51	0	0	0
2.71	0	0	0
1.39	7	3	10
2.39	4	0	4
4.03	6	1	7
3.94	5	1	6
4.44	7	3	10
2.59	16	2	18
3.03	11	1	12
2.41	5	1	6
3.36	1	1	2
3.21	6	4	10
4.02	0	0	0
6.58	0	0	0
6.23	0	0	0
3.34	0	0	0
23.09	0	0	0
3.88	2	2	4
182.84	150	30	180

Core area, moose statistics, 1982.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR STRATUM

Surface area for stratum = 1375.3 km^2
 Total number of S.U.'s in stratum = 361
 Number of S.U.'s sampled = 48
 Mean S.U. area = 3.8
 % of stratum sampled = 13.3

Moose estimate = 1354
 Moose/ km^2 = 1.0

Variance of estimate = 70854.4
 Sample variance = 30.1
 % of coefficient of variation = 19.7
 Relative variation factor = 1980.5

POPULATION SUMMARY

Total surface area = 1375.3 km^2
 Total number of S.U.'s = 361
 Total number of S.U.'s sampled = 48
 % of area sampled = 13.3

Moose estimate = 1354
 Moose/ km^2 = 1.0

Variance of estimate = 70854.4
 % coefficient of variation = 19.7

Degrees of freedom (DF) = 31
 Confidence level (CL) - 90%
 T-value = 1.684
 Upper confidence level = 1802
 Lower confidence level = 906
 CL as a % of estimate = 33.1

Core area, moose data, 1985.

Plot size(km ²)	bulls	cows	calves	total
3.34	1	0	0	1
4.04	0	0	0	0
2.91	0	0	0	0
2.89	0	3	0	3
3.26	0	7	2	9
3.79	0	2	0	2
2.54	1	0	0	1
9.61	0	0	0	0
3.68	1	0	0	1
3.01	0	0	0	0
4.18	1	4	1	6
1.84	4	0	0	4
3.39	0	0	0	0
2.89	0	0	0	0
2.79	0	0	0	0
2.81	0	2	0	2
3.76	0	0	0	0
4.34	0	0	0	0
4.28	0	1	0	1
4.71	0	1	1	2
1.02	1	2	0	3
3.24	0	0	0	0
1.67	0	7	4	11
1.55	0	0	0	0
3.34	0	2	0	2
3.79	0	0	0	0
2.77	0	0	0	0
3.16	0	0	0	0
2.41	0	1	1	2
2.67	1	0	0	1
2.51	0	0	0	0
2.71	0	2	0	2
1.39	1	4	1	6
2.39	1	2	3	6
4.03	2	9	2	13
3.94	1	1	1	3
4.44	1	11	4	16
2.59	0	0	0	0
3.03	2	5	1	8
2.41	1	0	0	1
3.36	0	0	0	0
3.21	1	5	2	8
4.02	0	0	0	0
6.58	0	0	0	0
6.23	0	2	1	3
3.34	4	1	1	6
23.09	2	4	2	8
3.88	2	4	3	9
182.84	28	82	30	140

Core area, moose statistics, 1985.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR STRATUM

Surface area for stratum = 1375.3 km^2
 Total number of S.U.'s in stratum = 361
 Number of S.U.'s sampled = 48
 Mean S.U. area = 3.8 km^2
 % of stratum sampled = 13.3

Moose estimate = 1053
 Moose/ km^2 = 0.8

Variance of estimate = 43398.5
 Sample variance = 18.4
 % of coefficient of variation = 19.8
 Relative variation factor = 1550.0

POPULATION SUMMARY

Total surface area = 1375.3 km^2
 Total number of S.U.'s = 361
 Total number of S.U.'s sampled = 48
 % of area sampled = 13.3

Moose estimate = 1053
 Moose/ km^2 = 0.8

Variance of estimate = 43398.5
 % coefficient of variation = 19.8

Degrees of freedom (DF) = 31
 Confidence level (CL) = 90%
 T-value = 1.684
 Upper confidence level = 1404
 Lower confidence level = 702
 CL as a % of estimate = 33.3



Appendix B.

Tierney area - moose data and statistics

Tierney area, moose data.

Plot Size (km ²)	Cows	Calves	Bulls	Total
LOW DENSITY				
12.5	3	1	0	4
7.8	2	2	1	5
10.0	10	3	1	14
4.8	2	1	0	3
4.3	9	0	7	16
12.7	1	1	0	2
8.0	11	2	3	16
7.8	5	1	0	6
5.2	5	1	0	6
7.4	2	0	0	2
7.3	10	2	4	16
7.7	2	0	0	2
4.5	1	1	5	7
7.5	9	0	3	12
6.7	10	5	6	21
114.2	82	20	30	132
HIGH DENSITY				
8.2	18	8	16	42
4.0	38	12	40	90
11.4	35	18	58	111
23.6	91	38	114	243

Tierney area, moose statistics.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR LOW DENSITY STRATUM

Surface area for stratum = 383.5 km^2
 Total number of S.U.'s in stratum = 50
 Number of S.U.'s sampled = 15
 Mean S.U. area = 7.6 km^2
 % of stratum sampled = 29.8
 Moose estimate = 443
 Moose/ km^2 = 1.2

Variance of estimate = 6873.4
 Sample variance = 58.0
 % of coefficient of variation = 18.7
 Relative variation factor = 383.8

SUMMARY TABLE FOR HIGH DENSITY STRATUM

Surface area for stratum = 23.6 km^2
 Total number of S.U.'s in stratum = 3
 Number of S.U.'s sampled = 3
 Mean S.U. area = 7.9 km^2
 % of stratum sampled = 100
 Moose estimate = 243
 Moose/ km^2 = 10.3

Variance of estimate = 0
 Sample variance = 2112.0
 % of coefficient of variation = 0
 Relative variation factor = 137.9

POPULATION SUMMARY

Total surface area = 407.1 km^2
 Total number of S.U.'s = 53
 Total number of S.U.'s sampled = 18
 % of area sampled = 33.8
 Moose estimate = 686
 Moose/ km^2 = 1.7

Variance of estimate = 6873.4
 % coefficient of variation = 12.1

Degrees of freedom (DF) = 14
 Confidence level (CL) - 90%
 T-value = 1.761
 Upper confidence level = 832
 Lower confidence level = 540
 CL as a % of estimate = 21.3

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Appendix C.

Pink area - moose data and statistics,
1979 and 1984

Pink area moose, February 1979 data.

Plot Size(km ²)	Bulls	Cows	Calves	Total
LOW DENSITY				
3.0	0	0	0	0
3.3	0	2	0	2
2.7	6	4	0	11 (1 u/c)
2.1	0	0	0	0
3.0	0	0	0	0
4.0	3	4	2	9
4.0	1	2	1	4
3.3	1	9	2	12
2.8	0	1	1	2
4.8	4	7	4	15
3.1	1	0	0	1
2.3	0	1	1	2
2.7	0	0	0	0
2.0	0	2	2	4
2.3	0	1	1	2
2.5	2	3	1	6
3.0	3	3	2	8
4.0	0	7	3	10
1.9	2	0	0	2
56.8	23	46	20	90
HIGH DENSITY				
2.3	3	1	1	6 (1 u/c)
2.5	2	2	0	4
4.8	5	3	1	10

Pink area moose, statistics, February 1979.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR LOW DENSITY STRATUM

Surface area for stratum = 615.4 km^2
 Total number of S.U.'s in stratum = 206
 Number of S.U.'s sampled = 19
 Mean S.U. area = 3.0 km^2
 % of stratum sampled = 9.2
 Moose estimate = 975
 Moose/ km^2 = 1.6

Variance of estimate = 33712
 Sample variance = 16.7
 % of coefficient of variation = 18.8
 Relative variation factor = 840.0

SUMMARY TABLE FOR HIGH DENSITY STRATUM

Surface area for stratum = 304.6 km^2
 Total number of S.U.'s in stratum = 127
 Number of S.U.'s sampled = 2
 Mean S.U. area = 2.4 km^2
 % of stratum sampled = 1.6
 Moose estimate = 634.6
 Moose/ km^2 = 2.1

Variance of estimate = 23148.2
 Sample variance = 2.9
 % of coefficient of variation = 24.0
 Relative variation factor = 216.9

POPULATION SUMMARY

Total surface area = 920.0 km^2
 Total number of S.U.'s = 333
 Total number of S.U.'s sampled = 21
 % of area sampled = 6.7
 Moose estimate = 1610
 Moose/ km^2 = 1.7

Variance of estimate = 56860.5
 % coefficient of variation = 14.8

Degrees of freedom (DF) = 5
 Confidence level (CL) - 90%
 T-value = 2.015
 Upper confidence level = 2090
 Lower confidence level = 1128
 CL as a % of estimate = 29.8

Pink area moose data; December 1984

Plot Size (km ²)	Bulls	Cows	Calves	Total
LOW DENSITY STRATA				
30.8	5	11	2	18
18.6	3	3	2	8
23.9	4	4	1	9
73.3	12	18	5	35
MODERATE DENSITY STRATA				
25.3	7	13	4	29 (5 u/c)
32.7	6	20	5	33 (2 u/c)
30.0	2	12	13	27
24.8	10	24	2	39 (3 u/c)
112.8	25	69	24	128
HIGH DENSITY STRATA				
26.7	13	23	2	38
25.0	14	33	13	60
29.8	8	32	18	58
25.6	21	42	7	70
27.9	8	24	8	42 (2 u/c)
135.	64	154	48	268

Pink area moose statistics, December 1984.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR LOW DENSITY STRATUM

Surface area for stratum = 344.7 km^2
 Total number of S.U.'s in stratum = 14
 Number of S.U.'s sampled = 3
 Mean S.U. area = 24.4 km^2
 % of stratum sampled = 21.3

Moose estimate = 165
 Moose/ km^2 = 0.5

Variance of estimate = 454
 Sample variance = 8.7
 % of coefficient of variation = 13.0
 Relative variation factor = 41.7

SUMMARY TABLE FOR MODERATE DENSITY STRATUM

Surface area for stratum = 871.6 km^2
 Total number of S.U.'s in stratum = 31
 Number of S.U.'s sampled = 4
 Mean S.U. area = 28.2 km^2
 % of stratum sampled = 12.9

Moose estimate = 989
 Moose/ km^2 = 1.1

Variance of estimate = 12788.6
 Sample variance = 61.5
 % of coefficient of variation = 11.4
 Relative variation factor = 242.3

SUMMARY TABLE FOR HIGH DENSITY STRATUM

Surface area for stratum = 135.1 km^2
 Total number of S.U.'s in stratum = 5
 Number of S.U.'s sampled = 5
 Mean S.U. area = 27 km^2
 % of stratum sampled = 100.0

Moose estimate = 268
 Moose/ km^2 = 2.0

Variance of estimate = 0
 Sample variance = 220.3
 % of coefficient of variation = 0
 Relative variation factor = 74.3

Statistics (con't)

POPULATION SUMMARY

Total surface area = 1351.4 km²
Total number of S.U.'s = 50
Total number of S.U.'s sampled = 12
% of area sampled = 23.8

Moose estimate = 14228
Moose/km² = 1.1

Variance of estimate = 13243.0
% coefficient of variation = 8.1

Degrees of freedom (DF) = 3
Confidence level (CL) - 90%
T-value = 2.353
Upper confidence level = 1693
Lower confidence level = 1151
CL as a % of estimate = 19.0

Appendix D.

Core area - elk data and statistics,
1982 and 1985

Core area elk data, 1982.

Plot Size (km ²)	Bulls		Cows	Calves	Total
	2+ yrs.	yr lg.			
LOW DENSITY STRATA					
2.59	0	0	0	0	0
4.66	1	0	5	1	7
3.89	0	5	0	0	5
4.40	0	0	3	1	4
3.37	0	0	3	1	4
2.59	0	0	0	0	4
2.59	0	0	0	0	0
2.59	0	0	0	0	0
1.04	0	0	0	0	0
3.37	0	0	0	0	0
1.55	0	0	4	0	4
1.55	1	0	0	0	1
2.59	0	0	0	0	0
1.30	0	0	0	0	0
2.33	0	0	0	0	0
4.14	0	0	0	0	0
3.37	0	0	1	0	1
3.37	0	0	0	0	0
3.37	0	3	0	0	3
3.89	1	0	0	0	1
2.59	0	0	1	0	1
4.14	0	0	0	0	0
3.63	0	1	0	0	1
4.14	0	1	0	0	1
3.37	0	1	0	0	1
4.40	0	0	0	0	0
2.85	0	0	0	0	0
3.89	0	0	0	0	0
4.40	0	11	0	0	11
3.89	0	0	6	0	6
95.83	3	22	23	3	51

Core area elk data, 1982, continued

Plot Size(km ²)	Bulls		Cows	Calves	Total
	2+ yrs	yr/ig.			
HIGH DENSITY STRATA					
2.85	0	8	7	3	18
2.85	0	0	15	2	17
3.11	5	0	16	2	23
1.81	1	0	19	5	25
2.85	0	0	9	3	12
2.85	0	4	19	3	26
3.89	1	0	20	7	28
2.85	2	1	5	0	8
2.59	7	1	17	3	28
3.11	3	0	16	3	22
3.11	0	3	14	5	22
3.11	2	4	21	5	32
34.97	21	21	178	41	261
VERY HIGH DENSITY STRATA					
4.14	2	1	50	5	58
6.48	2	0	35	2	39
6.22	1	0	40	8	49
9.58	9	13	90	9	121
3.37	1	0	40	9	50
23.05	41	39	504	81	665
52.04	56	53	759	114	982

Core area elk statistics, 1982.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR LOW DENSITY STRATUM

Surface area for stratum = 1028.2 km^2
 Total number of S.U.'s in stratum = 322
 Number of S.U.'s sampled = 30
 Mean S.U. area = 3.2 km^2
 % of stratum sampled = 9.3

Elk estimate = 547
 $\text{Elk}/\text{km}^2 = 0.5$

Variance of estimate = 19816.8
 Sample variance = 6.3
 % of coefficient of variation = 25.7
 Relative variation factor = 809.7

SUMMARY TABLE FOR HIGH DENSITY STRATUM

Surface area for stratum = 373.0 km^2
 Total number of S.U.'s in stratum = 128
 Number of S.U.'s sampled = 12
 Mean S.U. area = 2.9 km^2
 % of stratum sampled = 9.4

Elk estimate = 2784
 $\text{Elk}/\text{km}^2 = 7.5$

Variance of estimate = 67615.9
 Sample variance = 54.6
 % of coefficient of variation = 9.3
 Relative variation factor = 946.2

SUMMARY TABLE FOR VERY HIGH DENSITY STRATUM

Surface area for stratum = 52.9 km^2
 Total number of S.U.'s in stratum = 6
 Number of S.U.'s sampled = 6
 Mean S.U. area = 8.8 km^2
 % of stratum sampled = 100.0

Elk estimate = 983
 $\text{Elk}/\text{km}^2 = 18.6$

Variance of estimate = 0
 Sample variance = 14158
 % of coefficient of variation = 0
 Relative variation factor = 714

Statistics, (con't)

POPULATION SUMMARY

Total surface area = 1454.1 km²
Total number of S.U.'s = 456
Total number of S.U.'s sampled = 48
% of area sampled = 12.6

Elk estimate = 4314
Elk/km² = 3.0

Variance of estimate = 87432.7
% coefficient of variation = 6.9

Degrees of freedom (DF) = 18
Confidence level (CL) - 90%
T-value = 1.734
Upper confidence level = 4827
Lower confidence level = 3801
CL as a % of estimate = 11.9

Core area elk data, 1985.

Plot Size (km ²)	Bulls		Cows	Calves	Total
	2+ yrs	yr/ig.			
LOW DENSITY STRATA					
2.33	0	0	0	0	0
4.66	0	0	3	0	3
3.37	0	0	5	1	6
2.33	0	0	0	0	0
2.59	0	0	0	0	0
2.59	0	0	0	0	0
1.04	0	2	9	5	16
3.37	0	0	0	0	0
1.04	2	0	5	1	8
1.55	0	0	3	0	3
2.59	0	0	0	0	0
1.30	0	0	0	0	0
2.33	1	0	6	4	11
4.16	0	0	0	0	0
3.37	0	0	0	0	0
3.37	0	0	0	0	0
3.89	0	0	0	0	0
2.59	0	0	5	2	7
4.14	0	0	1	1	2
3.63	0	0	0	0	0
4.14	0	0	3	1	4
3.37	0	2	0	0	2
4.40	0	0	0	0	0
2.85	0	0	3	2	5
3.89	0	0	0	0	0
4.40	0	0	0	0	0
3.89	1	1	14	7	23
83.14	4	5	57	24	90

Core area elk data, 1985, continued

Plot Size (km ²)	Bulls		Cows	Calves	Total
	2+ yrs	yr/ig.			
HIGH DENSITY STRATA					
2.85	0	0	7	3	10
2.85	0	0	1	1	2
3.11	0	1	3	2	6
1.81	1	0	8	5	14
2.85	0	0	12	3	15
3.11	0	0	6	3	9
3.89	0	0	2	1	3
2.85	1	2	29	12	44
2.59	0	0	12	1	13
3.11	0	3	28	7	38
3.11	0	0	14	15	29
3.17	1	3	3	2	9
3.37	3	0	35	13	51
3.89	3	8	0	0	11
4.40	0	0	12	6	18
46.88	9	17	172	74	272
VERY HIGH DENSITY STRATA					
4.14	7	4	33	13	57
6.48	0	0	36	12	48
6.22	1	1	43	13	58
9.58	0	0	44	8	52
3.37	1	0	65	32	98
23.05	3 20	28	03	105	456
52.84	5 29	33	24	183	769

Core area elk statistics, 1985.

CALCULATION OF MEAN DENSITY AND CONFIDENCE INTERVALS.

SUMMARY TABLE FOR LOW DENSITY STRATUM

Surface area for stratum = 981.6 km^2
 Total number of S.U.'s in stratum = 319
 Number of S.U.'s sampled = 27
 Mean S.U. area = 3.1 km^2
 % of stratum sampled = 8.5

Elk estimate = 1063
 $\text{Elk}/\text{km}^2 = 1.1$

Variance of estimate = 123250.8
 Sample variance = 35.8
 % of coefficient of variation = 33.0
 Relative variation factor = 1906.7

SUMMARY TABLE FOR MODERATE DENSITY STRATUM

Surface area for stratum = 419.6 km^2
 Total number of S.U.'s in stratum = 134
 Number of S.U.'s sampled = 15
 Mean S.U. area = 3.1 km^2
 % of stratum sampled = 11.2

Elk estimate = 2434
 $\text{Elk}/\text{km}^2 = 5.8$

Variance of estimate = 260364.2
 Sample variance = 244.0
 % of coefficient of variation = 21.0
 Relative variation factor = 2097.1

SUMMARY TABLE FOR VERY HIGH DENSITY STRATUM

Surface area for stratum = 52.9 km^2
 Total number of S.U.'s in stratum = 6
 Number of S.U.'s sampled = 6
 Mean S.U. area = 8.8 km^2
 % of stratum sampled = 100.0

Elk estimate = 770
 $\text{Elk}/\text{km}^2 = 14.6$

Variance of estimate = 0
 Sample variance = 5555.5
 % of coefficient of variation = 0
 Relative variation factor = 447.6

Statistics, continued

POPULATION SUMMARY

Total surface area = 1454.1 km²
Total number of S.U.'s = 459
Total number of S.U.'s sampled = 48
% of area sampled = 12.6

Elk estimate = 4267
Elk/km² = 2.9

Variance of estimate = 383615.0
% coefficient of variation = 14.5

Degrees of freedom (DF) = 27
Confidence level (CL) - 90%
T-value = 1.703
Upper confidence level = 5322
Lower confidence level = 3212
CL as a % of estimate = 24.7